

Impulse Noise from Automotive Inflatable Devices**RATIONALE**

The sample rate advocated for noise measurements in 2003 was "50 kHz" however when J247 was completed we decided "48 kHz" was more appropriate. To maintain consistency between these two documents I went ahead and made that same change, so now J2531 advocates "48 kHz".

The reason for advocating any sampling rate at all was to maintain consistency between test labs.

FOREWORD

All acronyms are defined in this document in Section 3.0 "Definitions."

a. Relationship of the document to other documents

The following organizations are involved in setting standards or recommendations for impulse noise analysis:

1. Arbeitskreis (AK)
2. American National Standards Institute (ANSI)
3. National Academy of Sciences/National Research Council, Committee on Hearing, Bioacoustics and Biomechanics (CHABA).
4. North Atlantic Treaty Organization (NATO) Research Study Group 29 on "Impulse Noise Effects"
5. U.S. Department of Defense (DOD)
6. U.S. Department of Transportation (DOT)

b. History, background, and introductory material.**1. Evolution of Impulse Noise Risk Assessment**

- (a) ca. 1960: Research into damage risk criteria for impulse noise centers on occupational exposure from steady state noise. Military research established the threshold for eardrum rupture at 180 dB for an unprotected ear with a free-field sound pressure wave at grazing incidence.
- (b) 1966: Criterion for steady state noise published by CHABA Working Group 46 (Kryter et al., 1966)

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- (c) 1968: First criterion specifically for impulse noise published by CHABA based on Coles et al. (1968). This criterion: lowered the tolerable pressure by 5 dB for normal incidence of noise wave to ear, lowered the allowable pressure by another 5 dB to protect 95% of population instead of 75% as in Coles et al., established 179 dB peak SPL over 25 microsecond duration as single impulse limit to unprotected ear, accounted for acoustic reflex contraction of middle ear muscles, and established a correction factor for single impulse exposures by permitting a 10 dB increase in allowable pressure. The method of signal analysis was also specified in this paper using the A and B-durations (see Definitions section). Lacking other tools, passive restraint engineers adopted these methods and criteria. Typical driver airbag systems produced impulses in the range of 140 to 150 dB. These were considered to be associated with a low risk for PTS.
- (d) 1969: Classic experiments with human volunteers exposed to automotive airbags performed and reported Nixon (1969).
- (e) 1971: Bolt, Beranek, and Newman revised earlier impulse noise criteria to specifically address impulse noise produced by airbag deployment (Allen et al., 1971). Raw pressure-time data was low-pass filtered at 300 Hz for A-duration calculation and high-pass filtered at 300 Hz for B-duration calculation. This method analyzes the low and high frequency data as if they act independently on the ear, without interaction between them.
- (f) 1973: Another classic set of human volunteer experiments conducted by Sommer and Nixon (1973). Volunteers were exposed to low frequency noise (by itself), high frequency noise (by itself) and low plus high frequency noise acting together. A protective effect of low frequency noise was suggested.
- (g) 1975: MIL-STD-1474A "Noise Limits for Army Materiel" first published. This standard established maxima for combinations of peak Sound Pressure Level and B-duration beyond which varying types of hearing protection are required by military personnel. These B-durations are calculated using the wideband pressure-time data collected (with the low and high frequency noise analyzed together in contrast to the BBN method).
- (h) 1987: SAE J247 (FEB87) Recommended Practice—Instrumentation For Measuring Acoustic Impulses Within Vehicles. Describes the instrumentation and procedure for measurement of airbag noise in vehicles.
- (i) 1992: National Academy of Sciences/National Research Council (1992) reports that "The 1968 criterion should not be used for low-frequency impulses such as air bags, sonic booms, rapid pressurization etc." The NAS decision was primarily based on the fact that the 1968 criterion did not account for the spectral distribution of the energy, the number of impulses, or the temporal spacing of the impulses.
- (j) 1996: A mathematical model of the feline ear is reported by Price and Kalb from the US Army Research Lab. The model calculates risk based on a hypothesis that damage to the hair cells in the cochlea correlates to a mathematical function of the number and amplitude of basilar membrane displacements in a manner analogous to mechanical fatigue of solid materials.
- (k) 1996: Math model of the feline ear is validated for airbag impulses (Price, Rouhana and Kalb, 1996; Price and Kalb, 1996). The model has a movie function that shows the development of the risk of impulse noise-induced threshold shift as it relates to the impulse noise pressure-time history.
- (l) 1997: MIL-STD-1474D "Noise Limits" a revision of MIL-STD-1474C. This standard continues the use of maxima for combinations of peak Sound Pressure Level and B-duration beyond which varying types of hearing protection are required by military personnel. The limits are referenced to the Curve X instead of Curve Y and Curve X is reduced by 1.5 dB from MIL-STD-1474B).
- (m) 1999: The ARL Ear model is extended to a human ear model (Price and Kalb, 1999).

- (n) 1999: ANSI Working Group S3-32 issued a draft report on the effects of impulse noise". The group recommended using the 8-hour equivalent energy (LAEQ8) criterion for impulse noise below a peak SPL of 140 dB, and the ARL criterion for impulse noise above a peak SPL of 140 dB.
 - (o) 2001: The ARL Ear Model was reviewed by a Peer Review Panel of the American Institute of Biological Sciences. The panel concluded that the Ear Model "represents a significant improvement over the Department of Defense Design Criteria Standard: Noise Limits of 12 February 1997 (MIL-STD-1474D).", that "the model was validated by human exposure data obtained in Albuquerque, New Mexico", and that "the HRED model can be used to test potential health hazards associated with impulse noise levels in excess of 140 dB".
2. Biomechanics of Hearing--Sound travels through the air as pressure waves. The external ear lobe (pinna) channels the sound into the ear canal and to the eardrum (tympanic membrane), where it is converted into vibrations of the ear ossicles called the malleus, the incus and the stapes (also known as the hammer, anvil, and stirrup). The ossicles are located in the middle ear cavity. The stapes is held in the oval window of the cochlea, or inner ear, by the annular ligament. When the stapes moves due to vibrations of incoming sound pressure, a pressure wave is transmitted down the fluid of the cochlea. The pressure wave distorts a membrane that runs along the length of the cochlea (basilar membrane). Within the cochlea's organ of Corti, thousands of microscopic hairs, embedded in hair cells resting on the basilar membrane, move when the basilar membrane is distorted. This causes the hair cells connected to the auditory nerve to generate electrochemical signals, which pass to the hearing centers of the brain, to be interpreted as sound. Hair cells near the base of the cochlea respond mainly to higher frequencies and those near the apex respond mainly to lower frequencies.
 3. Human Biovariability Distinct age populations have different hearing acuity. For example, the elderly typically show distinct changes in hearing from their middle age capability (this is called presbycusis—45% of Americans over age 75 are affected). The feline subject is a human surrogate with hearing acuity similar to that of people, although it is viewed overall, as having significantly greater acuity than humans.

The presence of a middle ear infection can reduce the transmissivity of the middle ear and lower the effective hearing acuity. It is unknown whether age or illness have any effect on risk of noise-induced hearing loss.

4. Mechanisms of Hearing Loss

1. Blow to the Head--gross mechanical failure of structures, such as fracture of ossicles and tearing of the eardrum.
2. Exposure to Continuous Noise--long duration (hours, weeks, months) exposures to loud noises, such as a rock concerts, heavy equipment, and pneumatic drills without ear protection. Hearing loss in continuous exposure is believed to be biochemical in nature.
3. Exposure to Impulsive Noise--physical trauma to the cellular structures of the cochlea. For example, the ARL Ear Model risk algorithm identifies the peaks of the upward displacement of the stapes that put the inner ear tissues in tension where they are most likely to sustain damage. Using the calculated stapes displacement as the driving input to the cochlea, the model calculates the displacement history of the basilar membrane for the duration of the input waveform. Risk is calculated at 23 locations along the basilar membrane. The postulated mechanism of injury in the algorithm is similar to mechanical fatigue of the hair cells in general engineering and is calculated as a function of the amplitude of the vibration and the number of cycles of vibration. The output of the ARL model calculation is presented in values called Auditory Risk Units [ARU].

1. SCOPE

New methods are available to assist in evaluating the risk of impulse noise-induced hearing loss from inflatable devices, for example, airbags and seat belt pretensioners. This document presents some background on impulse noise measurement techniques and assessment criteria. Related information relative to test details, for example, preamplifier specifications and filtering methods and criteria, will be discussed in a future recommended practice.

1.1 Purpose

This document serves to disseminate information about these tools and techniques to assist the automotive restraint development process.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

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2.1.4 DoD Publications

Available from U.S. Government Printing Office, Sales Management Division (SSMB), Washington, DC 20402.

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2.1.5 NATO Publications

Available from Directorate of Standardization, Stan 2, Kentigern House, 65 Brown Street, GLASGOW G2 8EX, United Kingdom

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3. DEFINITIONS

3.1 Acronyms

AHAHAH	Auditory Hazard from Airbags—Human (human ear model from ARL)
ARU	Auditory Risk Units output from ARL ear model
AK	Arbeitskreis der Ruckhaltesysteme-Kooperation, Working Committee of German Automobile Manufacturers
ANSI	American National Standards Institute
AHTL	Average Hearing Threshold Level
ARL	Army Research Laboratory
BAEP	Brainstem Auditory Evoked Potentials
BBN	Bolt, Berenak, and Newman
CHABA	Committee on Hearing, Bioacoustics and Biomechanics, National Research Council, National Academy of Sciences
dB	Decibels, logarithmic scale for sound pressure or power units
DOD	Department of Defense (United States)
DOT	Department of Transportation (United States)
ISO	International Standards Organization
NATO	North Atlantic Treaty Organization
NIHL	Noise-induced hearing loss
OAE	Otoacoustic Emissions
PB	phonetically balanced
PTS	permanent threshold shift in hearing (hearing loss that does not fully recover; see Threshold Shift below)
SAE	The International Engineering Society for Advancing Mobility Land Sea Air and Space
SL	Sensation Level (speech intensity)

SPL	Sound Pressure Level = $20 \log$ (measured Pressure/reference Pressure)
TC	Technical Committee
TTS	temporary threshold shift in hearing (hearing loss that recovers; see Threshold Shift below)
WG	Working Group

3.2 Definitions

3.2.1 ACOUSTIC REFLEX

Transmission of sounds through the middle ear can be attenuated by means of the middle ear muscles (Tensor Tympani and Stapedius Muscle). These muscles are triggered by the Trigeminal and Facial nerves. The Acoustic Reflex, can cause contraction of these muscles and can be elicited by loud sounds, vocalization, tactile stimulation of the head or general body movement (Pickles, 1988). This reflex is absent in 6.7% of "normal hearing" adults.

3.2.2 ACOUSTIC TRAUMA

Hearing loss or other auditory disturbance associated with exposure to a loud noise or series of loud noises.

3.2.3 A-DURATION

A measurement of the length of time of the low frequency component of an impulse noise pressure-time history. It is calculated from the first rise above the ambient pressure to the time the pressure first returns to zero.

3.2.4 ALPHA CABIN

A reverberation chamber having linear dimensions one-third of those of an international standard reverberation room. Its volume is 6.44 m^3 and no two walls are parallel. The overall dimensions are (L x W x H): $3.22 \times 2.37 \times 2.03 \text{ m}$. The cabin may be lined in with absorptive material on walls and floor to match the reverberation of a typical passenger compartment. This can be achieved, for example, by using 20-60 mm thick fibrous cotton fleece. The absorption characteristics in closed spaces can be described by determining the reverberation time, which should lie between 30 and 100 ms for frequencies from 0.5 to 8 kHz.

An airbag module (driver, front passenger, side, kneeblocker airbag) can be attached to the interior of the cabin door. A dummy torso fitted with pressure transducers or microphones can be positioned in the cabin as it would be in a vehicle (i.e., sitting in a car seat) with respect to the airbag. The system is triggered externally. In the case of multiple inflatable systems, the triggering can take place simultaneously or with a time delay between devices. The pressure rise from initiation of the device can be used to trigger a data acquisition device (e.g., a tape recorder or computer).

3.2.5 ARMY RESEARCH LAB [ARL] MODEL

A mathematical model of the ear that calculates the risk of impulse noise-induced threshold shift from a pressure wave. The "risk" is a measure of the mechanical fatigue of the hair cells of the cochlea. The model consists of transfer functions that characterize the incident sound pressure as it moves from the free field to the inner ear. The feline model is validated for airbag exposure. The human version of the model has been validated using military volunteers who had been exposed to impulse noise from large weapons. The ARL Model represents the ear as electroacoustic elements with inductors representing mass, capacitors representing acoustic compliance, and resistors representing acoustic resistances. The model includes graphs of transfer functions—free-field pressure to eardrum pressure; external ear radiation impedance; eardrum acoustic input impedance; eardrum pressure to stapes volume velocity; free-field pressure to stapes volume velocity; and stapes displacement to basilar membrane displacement. The model represents the stapes as nonlinear. At low intensities, the annular ligament exerts a linear restoring force on the stapes and can displace easily up to 5 to 6 μm . At high intensities, the restoring force is nonlinear, reaching an asymptote at about 20 μm , limiting the motion of the stapes. Under some circumstances, this nonlinearity appears to limit the transmission of higher frequency noise to the inner ear.

3.2.6 ASYMMETRIC HEARING LOSS

Hearing loss in an ear that is of different magnitude than that in the other ear. There is no general agreement on how big the difference must be, but some studies suggest that the difference must be ≥ 15 dB at two frequencies or there must be a difference in speech discrimination of $\geq 15\%$ in order for the hearing loss to be considered asymmetric.

3.2.7 AUDIOGRAM

A graph for a given ear of hearing thresholds obtained for various frequencies.

3.2.8 AVERAGE HEARING THRESHOLD LEVEL (ANSI, 1969)

The softest level at which a patient can correctly repeat 50% of presented "spondee words"; it is recorded in decibels hearing level (dBHL). A spondee word is a two-syllable word, each syllable of which can stand alone as a separate monosyllabic word. Some examples are "baseball, hotdog, airplane, and mushroom".

3.2.9 B-DURATION

A measurement of the decay time of the high frequency component of the pressure from an impulse noise waveform. It is measured from the time the pressure first rises above the baseline until the time that pressure is less than 20 dB of the peak, including all reflections. It is assumed that the B-duration represents the energy emitted at high frequencies, (e.g., the gas generation—gas jetting through a manifold, the airbag cushion unfolding, etc.

3.2.10 BRAINSTEM AUDITORY EVOKED POTENTIALS (BAEP)

Electrical activity within the auditory regions of the nervous system (auditory nerve or auditory regions of the brain) that is produced by sound and is measured via electrodes on the scalp.

3.2.11 C-WEIGHTING

Modification of the frequency content of a signal using a filtering network to more closely approximate the equal loudness contours of the human ear (see below).

3.2.12 COMPOSITE PULSE

The impulse noise waveform containing all the frequencies.

3.2.13 THE EAR

3.2.13.1 External Ear

Auricle or pinna and external auditory canal. The auricle and external auditory canal can amplify sound. The auricle also functions as a focusing organ and directs (high frequency) sounds into the ear canal.

3.2.13.2 Middle Ear

Tympanic membrane (ear drum), the malleus (hammer), incus (anvil), and stapes (stirrup) bones plus soft connective tissues (suspensory ligaments, the tensor tympani muscle, and the stapedius muscle). The middle ear functions as an acoustic transformer by matching the impedance of the air to that of the inner ear fluids.

3.2.13.3 Inner Ear

Cochlea and semicircular canals.

3.2.14 EARDRUM RUPTURE

A tear in the eardrum. A peak sound pressure level of 180 dB is commonly accepted as the threshold for eardrum rupture.

3.2.15 EQUAL LOUDNESS CONTOURS

Curves of perceived loudness as a function of frequency for pure tones arriving at the ear. The human ear responds differently to different frequencies. It is most sensitive to sounds at 4 kHz, and less sensitive at lower frequencies and higher frequencies (e.g., a 42 dB tone at 4 kHz sounds as loud as a 50 dB tone at 1 kHz and a 73 dB tone at 50 Hz).

3.2.16 DYNAMIC RANGE OF HEARING

20 μ Pa to 1 kPa at 20 Hz to 20 kHz; speech is transmitted between 500 Hz and 4 kHz.

3.2.17 GRAZING INCIDENCE

Noise wave directed parallel to the eardrum.

3.2.18 HEARING IMPAIRED / MILD HEARING LOSS (ANSI, 1969)

A hearing loss at least equal to 26 to 40 dB. Individual demonstrates difficulty understanding soft-spoken speech.

3.2.19 HEARING LEVEL

Audiometric test tones are specified in hearing level (HL) rather than SPL because the normal ear is not equally sensitive to low and high frequency sounds. According to current standards (ANSI, 1969) it takes 39 dB more SPL for the normal ear to barely hear a 125 Hz tone than it does to barely hear a 1000 Hz tone. Because it is desirable to have a 0 dB dial reading at the point where the normal ear can just barely hear the stimulus, regardless of frequency, the audiometer has been designed to compensate for differences in hearing sensitivity as a function of frequency.

3.2.20 HYPERACUSIS

See Recruitment.

3.2.21 IMPULSE NOISE

High amplitude, short duration noise, such as from military weapons or fireworks e.g. sound having a microsecond to millisecond rise of waveform with large amplitude (140 to 170 dB) and short durations of 2 to 500 ms; for example, airbags and seat belt pretensioners may produce impulse noise.

3.2.22 INTOLERANCE TO LOUDNESS

Patient is uncomfortable in loud/noisy environments after exposure to impulse/other noise.

3.2.23 MODERATE HEARING LOSS (ANSI, 1969)

41-55 dB. Individual demonstrates an understanding of speech at close range, but requires amplification.

3.2.24 NORMAL INCIDENCE

Noise wave directed perpendicular to the eardrum.

3.2.25 OCCULT SHIFT / HIDDEN SHIFT

Loss in the 4000+ to 6000 Hz range which is above the speech frequency range of 500 to 4000 Hz, and may not be apparent without comparison of pre- and post-exposure audiograms.

3.2.26 OTOACOUSTIC EMISSIONS (OAE)

Acoustical signals that can be detected in the ear canal spontaneously as narrow band tonal signals after stimulation of the ear and are thought to be due to vibrations produced at various locations within the cochlea.

3.2.27 PERMANENT THRESHOLD SHIFT

A change in hearing secondary to noise exposure that is permanent (remains longer than 6 months).

3.2.28 PEAK AMPLITUDE

The maximum value of sound pressure attained, expressed in psi (kPa). It may also be expressed as sound pressure level in decibels (dB).

3.2.29 PROFOUND HEARING LOSS (ANSI, 1969)

91+ dB. Person does not rely on hearing as the primary modality for communication.

3.2.30 RECRUITMENT

Abnormal phenomenon of loudness sensitivity. As one raises the intensity of a tone, the perceived loudness grows more rapidly than in a normal ear.

3.2.31 REVERBERATION TIME

The time in a closed compartment in which the sound pressure level is reduced by 60 dB after the sound source is cut off. To be representative of a passenger vehicle, the reverberation time should lie between 30 and 100 ms for frequencies from 0.5 to 8 kHz.

3.2.32 RISK

In the ARL model, a measure of the mechanical fatigue of the hair cells in the inner ear.

3.2.33 SENSATION LEVEL (SL)

A measure of stimulus intensity relative to the threshold of the individual being tested. Thus, 30 dB SL means 30 dB above the individual's threshold for the specific test stimulus. The term SL often is used to specify the level at which speech discrimination tests are administered.

3.2.34 SEVERE HEARING LOSS

71 to 90 dB. Loud speech may be understood at 1 ft from the ear.

3.2.35 SHADOWING

Head shadowing occurs when the pressure wave of a noise event passes the head of an individual exposed to the noise. Since the head is positioned between the noise source and the distal ear, if the distal ear falls in the shadow of the head relative to the noise source it is exposed to a lower pressure than the proximal ear. For example, the study by Price, Rouhana and Kalb (1996) showed an approximately ten-fold reduction in ARUs by head shadowing.

3.2.36 SOUND PRESSURE LEVEL

Twenty times the base 10 logarithm of the ratio of the pressure of a sound to a reference pressure, expressed in decibels. The standard reference pressure is equal to 20 μPa . A 50 dB SPL tone is 50 dB above the reference pressure, 0.0002 dynes/cm². $\text{SPL} = 20 \text{Log}_{10}(\text{P}_{\text{measured}}/\text{P}_{\text{reference}})$

3.2.37 SPEECH DISCRIMINATION SCORE

The percentage of phonetically balanced (PB) words a person can correctly repeat at a given sensation level

3.2.38 TEMPORARY THRESHOLD SHIFT

A change in hearing secondary to noise exposure that recovers within 6 months.

3.2.39 THRESHOLD OF HEARING / HEARING LEVEL

The difference in decibels between a standard average threshold level (ISO R389) and the threshold of hearing for the individual being tested. The human ear perceives sound from 20 Hz to 20 kHz.

3.2.40 THRESHOLD SHIFT

A change in a person's hearing sensitivity after exposure to a sound; a temporary shift (TTS) disappears within 6 months and a permanent shift (PTS) is one that remains longer than 6 months.

3.2.41 THRESHOLD OF PAIN

120 to 140 dB, subject to human Biovariability.

3.2.42 TINNITUS

Subjective sensation of noise in the ear, ringing of the ears; an irritating repeatable sound in the ear.

3.2.43 VERTIGO

A sensation of motion when there is no physical movement.

3.3 Symbols

m ³	cubic meter
dB	decibels
dyne/cm ²	dyne per square centimeter = 1 newton per square meter
kPa	kiloPascals
m	meter
N/m ²	1 Newton per square meter
Pa	Pascal = 1 newton per square meter
μPa	1 microPascal
psi	1 pound per square inch
rms	root mean squared
μm	1 micrometer

4. TESTING CONSIDERATIONS FOR ASSESSMENT OF IMPULSE NOISE FROM INFLATABLE DEVICES

A number of issues remain unresolved relative to the test procedures for impulse noise. These issues are discussed in this section, even as researchers continue to develop and compare various test methods. This section will likely be revised within a year of the publication of this Information Report.

One of the principal issues surrounding airbag noise measurement is whether to measure in a vehicle environment or in a chamber that simulates a vehicle. While research to-date has shown a strong effect of vehicle environment on the risk predicted by the ARL model of the ear, suppliers of automotive components do not usually have access to prototype vehicles when the development of an inflatable device begins. Thus, they have no way to assess the impulse noise-induced hearing loss risk until very late in the vehicle development process when changes can affect program timing. It is likely that a recommended practice will suggest initial tests in a simulated vehicle environment followed by confirmation tests when a prototype vehicle is available.

Dynamic testing for assessment of airbag noise-induced threshold shifts is not necessary for a number of reasons. First, the noise of a crash itself is typically much less than that of the deployment of inflatable devices (145 dB vs 165 dB for a typical full frontal airbag system, respectively). Second, most transducers available today possess significant acceleration sensitivity. This sensitivity to acceleration makes it difficult to obtain accurate measurements of the noise during the crash.

4.1 Simulation of a Vehicle Using a Reverberation Chamber

Issues to be considered in the selection of a standardized chamber include:

- What volume is typical of a vehicle's passenger compartment?
- What are the acoustic properties inside of a vehicle?
- Should the ratio of glass to plastic trim be simulated?
- Should dummies be included?
- Should the chamber be airtight or have calibrated pressure relief?
- Suitability of chamber for head curtain airbags?

One chamber that has been proposed for use is called the Alpha Cabin (by Rieter Automotive). The Alpha Cabin can be vented or have pressure relief. It can be trimmed to represent the vehicle's expected acoustic characteristics. For example, by using 20 to 60 mm thick fibrous cotton fleece, absorption characteristics similar to those in a vehicle can be simulated.

Dummies should be used to represent the volume taken up by humans in a vehicle—especially the acoustical influence of the upper body.

The measuring transducers should be located at positions closely related to human ear locations.

Whether the windows are open or closed has produced different results in different experiments: driver-only systems did not show a difference, but driver and passenger systems deployed together have shown a significant difference.

Since early in the design of an airbag system, an exemplar vehicle is not available, it is desirable to have a standard chamber or tank that can be utilized by the airbag supplier for initial evaluations of prototype systems. This chamber or tank dimensions and composition should be standard to allow its availability worldwide to reduce the likelihood of lab-to-lab variation such as that which occurs in anechoic chambers.

4.2 Test Setup

Issues considered in the definition of Test Setup:

4.2.1 Acceleration of test fixture

Dynamic testing for evaluation of airbag noise is not recommended, but if a dynamic vehicle crash is being measured with the measuring equipment inside the vehicle, this equipment must be protected from vehicle deceleration. Most pressure transducers have specified acceleration sensitivity. The transducer should be oriented with its least sensitive axis in the direction of principal vehicle deceleration.

4.2.2 Grounding/charge coupling

All equipment including the dummies should be connected to a good earth ground. Sharp, large amplitude spikes in the data may indicate a grounding problem. Be careful not to introduce ground loops.

4.2.3 Mounting of the inflatable device(s)

4.2.3.1 In-Vehicle

Mount airbags in design location

4.2.3.2 In-Chamber

Attach the inflatable device in a manner similar to its in-vehicle orientation relative to the dummy. In the Alpha Cabin the device is mounted on the interior of the door to the cabin. The dummy torso fitted with the pressure transducers/microphones is positioned appropriately with respect to the inflatable device(s).

4.2.4 Electromagnetic Interference

Care should be taken to ensure proper grounding of all segments of the dummy to a good earth ground to prevent electrostatic discharge during the tests. Electrostatic discharge can masquerade as a noise signal.

4.2.5 Impact by Inflatable Device

Impact by an airbag or other inflatable device can also masquerade as a noise signal. Therefore, care should be taken to mount the sensor (pressure transducer or microphone) in a location that is outside the zone of inflatable device deployment.

4.2.6 Temperature

Tests should be conducted at room temperature, e.g. $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

4.2.7 Occupants

Do not test the vehicle/chamber empty: simulate the space that occupants would take up in the vehicle. Upper body acoustic parameters are important. Research is underway to determine whether all occupant seating positions should be occupied during the assessment or if just occupying those positions closest to the inflator would be sufficient.

4.2.8 Occupant Position Relative to the Inflatable Device

The head's closeness and orientation to the packaging of the inflator should to be considered. For example, a side airbag packaged in a right front passenger seat might be closer to the ear of a six-year-old dummy than to that of a 50th percentile Male dummy.